CHAPTER FOUR

PHOTOGRAMMETRY

BUREAU OF DESIGN AND ENVIRONMENT

SURVEY MANUAL

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I. INTRODUCTION

The Aerial Surveys Section in the Bureau of Design and Environment produces digital maps by photogrammetric means from aerial photography. The digital data is compiled in a three-dimensional (3D) format and is used to produce topographic maps and cross sections or digital terrain modeling (DTM) elevations. Horizontal and vertical field control is required to scale and orient a strip or block of photography. The Aerial Surveys Section uses analytical aerotriangulation procedures to establish additional photo control in the office environment. This additional control supplements the field control data to provide the required control to perform photogrammetric mapping.

The Division of Highway's district offices or the Central Bureaus initiate most of the mapping projects completed by the Aerial Surveys Section. All mapping requests should be coordinated through the respective mapping coordinator for the office requesting the topographic mapping.

The Aerial Surveys Section is responsible for obtaining the aerial photography and properly identifying the ground control requirements for the photography.

II. GENERAL

A. DEFINITIONS

Definitions of some of the common terms used in photogrammetry are listed below.

Analytical Control: The photo control that is developed by analytical aerotriangulation procedures to supplement field control.

Breaklines: Map lines consisting of "xyz" data points that define linear terrain features that have a uniform slope on either side of the line.

Contact Print: A one to one scale print from the aerial negative. The size of this photo is 9" x 9" (228 mm x 228 mm).

Contour: An imaginary line on the ground, all points of which are at the same elevation.

Conventional Control Point: A photo control point that is located by ground survey procedures.

Culture: Features of the terrain that have been constructed by man.

Design Mapping: Detailed map usually at a scale of 1:600 or 1:500. Vertical relief data is provided to an accuracy to create one foot or 0.25 meter contour intervals.

Digital Terrain Modeling (DTM): is a process for developing a mathematical model of the existing terrain from collected elevation data that is referenced to a coordinate system.

Endlap: The amount by which one photograph covers the same area as covered by the successive photograph along the flight strip. To be suitable for mapping, this amount shall be between 55 and 65%.

Flight Strip: A succession of aerial photographs taken along a single flight line.

Hang-Out Point: A targeted or post-controlled control point that is not part of a horizontal traverse.

Horizontal Picture Point (HPT): A photo identifiable horizontal control point that is horizontally positioned by a field survey.

Location Mapping: A broad base map at a scale of 1:2400 or 1:2500. The vertical relief data is provided to an accuracy to create five feet or 1.5 meter contour intervals.

Mass Points: Mass points area a series of “xyz” data points read on a predetermined grid pattern. The grid pattern spacing is determined by the terrain characteristics. On steep slope areas the pattern must be more closely spaced, whereas, in flat terrain the grid pattern can have a larger spacing.

Pass Point: A photo control point developed and used in the analytical triangulation process that ties adjacent photographs together. The analytical aerotriangulation process develops “xyz” values for each selected pass point .

Photo Control Point: A photo identifiable point identified on a photograph and having a horizontal and/or vertical position. A series of photo control points provides for the scaling and leveling control for the photogrammetric process.

Photo Identifiable: A point or feature that is identifiable on both the aerial photograph and the ground.

Photo Index: The photo index is a reduced scale copy of the project aerial photography. It consists of a photographic copy of the composite of all the contact prints laid out by flight strips showing the relationship of all the photos in the project.

Planimetric Features: Those features appearing on a map that represent natural features and cultural features. Natural features include rivers, lakes, mountains, valleys, forests, marshes, wetlands, etc. Cultural features include cities, farms, transportation routes, public utilities and facilities, etc.

Post Control: Post control consists of photo identifying horizontal and vertical picture points after the photography has been obtained.

Quality Control Point (QP): A point that is used as a vertical check on the photogrammetric process. It is a field-surveyed point.

Side Lap: The amount of overlap between two or more parallel flight lines. For mapping projects this amount should be a minimum of 30%.

Stereo Model: The three dimensional image formed by two successive overlapping photographs.

Target: An artificial symmetrical pattern that is placed over a control point before aerial photos are taken. Targets are used as horizontal and/or vertical control points. Also called a “panel”.

Vertical Picture Point (VPT): A vertical control point that is photo identifiable and has been vertically positioned by a field survey.

Wing Point: A picture point located within 20% of the outside edges of the photograph and normally used for vertical control.

B. MAPPING REQUEST

All mapping compiled by the Aerial Surveys Section is done by request. A mapping request form should be completed and sent to the Aerial Surveys office along with a map segment delineating the area to be mapped. See Figure 4.1, page 4-16 for a copy of a mapping request form.

C. TARGETS FOR AERIAL SURVEYS

To make it easier to photo identify photogrammetric ground control, selected points on the ground are targeted with contrasting panels of material consisting of cloth, paint, or plastic, etc. These panels are made to specific dimensions and color depending on the scale of the photography and the color of the background where the targets are to be placed.

C.1 Target Size

Targets must be of a size which will show up adequately on the particular scale of the photography being used, but should not be over sized as this would reduce precision in measuring their position on the photos. The type of target normally used for design mapping is a muslin material with a black background and a four inch white strip forming a cross. Targets used for location studies mapping is made of a nylon material and comes in a reversible black/white 1000 foot roll in either a six or twelve inch width. The size used is based on the flight height. At some locations, paint may be the most economical material to use for targets and the size must adhere to the project requirements.

C.2 Target Color

Target color must take into consideration the background on which the target will be placed. When placing targets on new (less than one year old) blacktop surfaces, a flat white striping paint may be used quite effectively. For placing targets on concrete pavement, flat black paint is preferable. In situations where there is a very white background surface the white background tends to bleed into the target. Therefore, a dark color wider than the standard width must be used. When placing targets off the roadway, similar ideas must be kept in mind for colors. In a plowed field with dark soil, white targets or light colored targets work the best. In a plowed field of light sandy material, a dark or black target is the better choice.

C.3 Placing the Targets

A target should always be placed in an area clear of overhead obstructions. The area should also be as level as possible. The target is to be placed as precisely as possible over the control point being used as photo control. Level ground is especially important if the target is to be used for vertical control. If the target is being placed over a monument or control point whose elevation is known, the difference between the monument surface and the ground surface must be measured and recorded. The surveyor must indicate whether the monument surface is recessed or projecting relative to the ground surface. The legs of the target should be placed at 45° to the natural background lines (cultivation lines, pavement edge, etc.).

Targets should be placed so that they can be seen from the sky. If possible, they should be located in open areas away from trees and their shadows, away from areas where cars park or stop, or may be obscured by moving vehicles. They must be placed where vandalism by humans or animals is minimized.

C.4 Pre-Targeted Projects

A pre-targeted project is one where target locations are pre-determined in the office. An enlarged photograph of the requested area to be mapped is used to indicate the locations of the horizontal and vertical control points and the quality control points. Horizontal control point locations are more difficult to predetermine and may have to be adjusted on the project site.

D. ANNOTATION OF PHOTOGRAMMETRIC CONTROL

The following numbering system should be used for annotating photogrammetric control points:

D.1 Projects that are Pre-Targeted for horizontal and vertical control.

D.1.1 Horizontal Control Points

Horizontal control points shall all be numbered with a four-digit number. The first two digits represent the calendar year the point was established. (i.e. 01 for the year 2001). The last two digits represent the sequential point number of the control point from 01-99. If a project has more than 99 horizontal points, contact the Aerial Surveys Section for numbering instructions. During the analytical bridging process a “9” is added in front of the four digit field number to label it as a horizontal control point for photogrammetric purposes. See Figure 4.2, page 4-17 for an example.

D.1.2 Vertical Control Points

Vertical control points shall all be numbered with a 7000 series number. See Figure 4.3, page 4-18 for an example.

D.1.3 Quality Control Points

Quality control points shall all be numbered with a 3000 series number. See Figure 4.3, page 4-18 for an example.

If a vertical or quality control point is subsequently used as a horizontal point, then a 9 is to precede the four-digit number assigned to that particular point to identify it as a horizontal control point.

D.2 Projects that are targeted for horizontal control only.

D.2.1 Horizontal Control Points

Horizontal control points shall all be numbered as described in section D.1.1 above. See Figure 4.2, page 4-17 for an example.

D.2.2 Vertical Picture Ties

Vertical picture ties (VPT) shall be numbered with a 7000 series number on even numbered photos. The 7000 number shall be selected to include the photograph number in the second and third digit location and the successive point number in the fourth digit location. See Figure 4.5, page 4-21 for an example.

D.2.3 Quality Control Points

Quality control points (QP) shall all be numbered with a 3000 series number when placed prior to photography acquisition. If a quality control point is photo identified on the photography, it shall be numbered by following the procedures used for a vertical picture tie. See Figure 4.3, page 4-18 or Figure 4.5, page 4-21 for examples.

D.2.4 Horizontal Picture Ties

A horizontal picture tie (HPT) shall be numbered with a four-digit 9000 number referencing the odd numbered photograph it lies on. The second and third digit is used for the photo number. The fourth digit is used to number the successive points on that photo. See Figure 4.4, page 4-19 for an example.

D.3 GPS Controlled Projects

All horizontal control points on GPS controlled projects shall be numbered with a four-digit number as described in section D.2.1 above. Control points established primarily for vertical control are to be numbered with a 7000 series number.

E. CONTROL PATTERN

The number of horizontal and vertical control points and the placement of the points relative to each photograph and each strip of photography shall be determined by the Aerial Surveys Section.

III. HORIZONTAL PHOTO CONTROL

A. FIELD REQUIREMENTS

If GPS technology is used to establish the horizontal positions for the control points, refer to "Specifications for GPS Surveys" in Appendix-F for the required procedures.

Horizontal photo control is required to be completed in the field to orient the aerial photography stereo models to a known horizontal grid to provide a true scale ratio of ground distance and position to that represented on the photography.

The traverse procedure requires eight angles to be measured at each traverse point and the distances to be measured in both directions. For points that are not included in the traverse but require horizontal positions, such as a hang-out point or a horizontal picture tie, four angles are required on both sides to close the horizon. The two sides should add up to 360 degrees.

The field measurements shall be performed according to the standards and requirements detailed in Table 3 of Chapter II, Section II, page 2-8 for Second Order, Class II surveys.

If practical, all mapping projects should be targeted for horizontal control. The spacing between targets depends upon the mapping scale and the layout of the project. Each project is unique and must be addressed on an individual basis for the appropriate target pattern.

In some cases a target may be destroyed before photography acquisition and a HPT will have to be obtained. There may also be a situation where a project is flown without targets and the entire project is post-controlled horizontally.

HPT's must be points that are easily photo identifiable and of such size and shape as to provide a clear and unmistakable identification of the exact image on the stereo model. Some examples of good HPT's are corners of sidewalk intersections, corners of driveway/sidewalk intersections, corners of drop inlets, etc. These points must be clearly described on the photographs and properly identified.

IV. VERTICAL PHOTO CONTROL

A. FIELD REQUIREMENTS

Vertical control is required to provide elevations at photo-identified locations (targets or VPT) on the ground by leveling through each required control point. A bench line through the project is required and photo control points should be leveled to and from this line. Level lines for photo control points should start and end at different bench marks (BM). Loops starting from and returning to the same BM shall be avoided. The leveling for vertical photo control is performed according to the standards and procedures detailed in Table 4 of Chapter II, Section II, page 2-10 for third- order control.

There are two procedures the Aerial Surveys Section presently uses to obtain the required vertical control. The primary method is to pre-target the project for vertical control before the project is flown. Target positions are pre-selected on an enlarged photograph of the mapping project and are located and placed in the field before the photography is obtained. The alternate method is to select the vertical picture ties after the project has been flown. The Aerial Surveys Section's field crew will receive a set of photos to take to the field and select the photo identifiable points for the vertical control.

In the second method, the field crew will be given the photos with circled areas where the VPT's are required. The final selection of VPT's should be done with a pocket stereoscope to view the photographs in stereo. The identified photo control points are then located in the field. Level lines are to be run through the selected points to determine their ground elevations. No side shots to a VPT are permitted. The survey procedure and the numbering system shall be as described in Section D on page 4-5.

The procedure for the pre-targeted projects is different in that the VPT's are all targeted prior to the flight and elevations are obtained for the targeted points as close as possible

to the same time as when the targets are set. The survey procedures and standards are the same as described for third-order control in Table 4 of Chapter II, Section II, page 2-10.

Quality control Points (QP) are similar to a VPT in their selection. A QP can also be pre-targeted. The procedure for the selection in the field is the same as the VPT's except that the pre-selected position will be along the centerline of the photograph, if possible. For pre-targeted projects the general location of the QP points will be shown on the enlarged photograph. Field survey procedures for these points are the same as for the VPT's.

If GPS technology is used to obtain the elevations for the vertical control points, refer to "Specifications for GPS Surveys" in Appendix-F for the procedures to use in obtaining the elevations.

V. CULTURE IDENTIFICATION

A. GENERAL

All mapping projects used for design purposes need to have culture identification completed in the field. For location mapping, only those features that are identified on the US Geological Survey 7.5 minute quadrangle maps will be identified on the location map unless the requester specifies otherwise.

All culture is to be identified on photo enlargements. Use a red ballpoint ink pen for all labeling. Label culture items within the limits outlined in red pencil on the enlargements provided by the Aerial Surveys Section.

B. UTILITIES

B.1 Fire Hydrant: Label = FH

B.2 Public Telephone: Label = TEL

B.3 Manholes

Identify the following manholes by using the label UMH:

- electric
- gas
- telephone

- sanitary
- traffic
- others

Identify the following manholes by using the label SMH:

- storm sewer

B.4 Poles

The surveyor need only label a sufficient number to clearly identify the type and location of the utility line or the location of those poles not clearly discernible on the photograph.

- Power: Label =..... ☐
- Telephone: Label = .. O
- Light: Label = ... O
- Guy Pole: Label = ... GP

B.5 Traffic Signals: Label = TS

B.6 Traffic Signal Control Box: Label = TCB

B.7 Catch Basin and/or Drop Inlets: Label = DI

B.8 Vent Pipes: Label = VP

B.9 Underground Utilities

Identify the following by using the label AGS (above ground splice):

- telephone
- gas
- electric
- others

C. TRANSPORTATION ROUTES

C.1 Names

- Routes
- Streets
- Railroads

C.2 Dimensions

Measure the width of the following to the nearest 3 hundredths of a foot or (10 mm):

- Pavement
- Shoulder
- Alley
- Curb and Gutter (identify end points)
- Bridges
- Culverts (diameter/box measurement)

C.3 Classification of all Driving Surfaces

- Concrete: ..... Label = PCC or CONC
- Bituminous: ..... Label = BIT
- Crushed Rock or Stone: . Label = ROCK
- Oil & Chips: ..... Label = O & C
- Earth: ..... Label = DIRT
- Brick: ..... Label = BRK

D. CLASSIFICATION OF STRUCTURES

- Residence: ..... Label = R (Includes Apartments)
- Commercial: ..... Label = C
- Shed: ..... Label = S
- Barn: ..... Label = B
- Garage: ..... Label = G
- School: ..... Label = SCHOOL
- Church: ..... Label = CHURCH
- Mobile Home: ..... Label = MH

E. DRAINAGE

E.1 River and Creeks

Identify all rivers and creeks by name, include a flow arrow.

E.2 Lakes and Reservoirs

Identify all lakes and reservoirs by name.

E.3 Culverts

Identify location of culverts that may not be clearly discernible on the photography.

VI. DELIVERABLES

Upon completion of the field work for a photogrammetric project, the following materials are to be delivered to the Aerial Surveys Section:

A. FIELD BOOKS

All pertinent field books or copies thereof for both the vertical and horizontal work are to be submitted. Any other material such as quad maps or sketches outlining the traverse and level lines or other field procedures used to control the project are to be included in the material submitted.

B. PHOTOGRAPHS.

All of the photographs containing culture information are to be submitted to the Aerial Surveys Section.

VII. COMPUTATIONS OF HORIZONTAL AND VERTICAL CONTROL

The computations of the field work for a mapping project must meet the following accuracy. The horizontal traverse closures must be in accordance with the accuracy as set forth in Chapter II, Section II, Table 3, page 2-8 for third order control. Likewise, the vertical control must meet the photogrammetric closures as stated in Chapter II, Section II, Table 4, page 2-10 for third order control. The Aerial Surveys Section in the Bureau of Design and Environment will assist the map requester in computing the photogrammetric horizontal and vertical control if they so desire.

VIII. DIGITAL TERRAIN MODELING

The Aerial Surveys Section will read digital terrain model information consisting of breaklines and mass points. Breaklines are lines that mark a change in slope such as ditch lines, ridge lines, edges of pavement, etc. Mass points are read on a predetermined grid pattern to fill in the areas around the breaklines. The purpose of the DTM is to expedite the design process. The DTM process has a significant impact in the design function because it permits the designer to generate existing cross-sections

and/or profiles at any interval along any alignment as long as Photogrammetry has captured enough data.

IX. ACCURACY TESTING OF PHOTOGRAMMETRIC DATA

This section discusses the accuracy testing of photogrammetrically derived contour maps and cross-sections. Accuracy testing is done to make sure the data resulting from the photogrammetric process correctly reflects the true ground conditions. Three different tests can be performed: 1) Planimetric, 2) Contour, and 3) Cross-Sections.

A. PLANIMETRIC TESTING

A base line will need to be established in a mapped area and referenced to the coordinate system of the map. Planimetric features can be located by distance and offset procedures from the base line as measured on the map to determine coordinates for the test points. The same base line is to be established in the field and objects located by measurements from the base line or the objects could be located in a radial survey using total station instrumentation. Coordinate values for common points can be compared and a statistical analysis done to determine the positional accuracy of the planimetric features of the map.

B. CONTOUR TESTING

A base line will need to be established as for planimetric testing. A profile can be read along this line at points where a contour crosses the base line. The same base line is to be established in the field and a profile of it obtained following third-order leveling procedures. A profile comparison is then run to determine the accuracy of the contour values and location.

C. CROSS-SECTIONS

A centerline will need to be established with stationing. Cross-sections are determined from the photogrammetrically read digital terrain model. The same centerline is to be established in the field. Field cross-sections shall be run at the same stations as the photogrammetric ones. A comparison is made between the photogrammetric and field values to analyze the accuracy of the photogrammetric sections.

D. FIELD PROCEDURES

For all map testing, good surveying procedures are required. Use only a 30" theodolite or better to measure right angle offset lines. Distances right and left of the centerline or base line should be measured with a steel tape to the nearest one tenth of a foot or (0.03 meters). Elevations should be read to the nearest one hundredth of a foot (0.005 meters). The Standard Deviation between the photogrammetric and the field cross-sections should be less than 1/4000 of the flight height for preliminary cross-sections on open ground and gentle slopes. See Table 1 below for other conditions and tolerances.

Table 1 Error as Fraction of Flight Height

Use and condition	Average (Algebraic mean)	Root Mean Square	For 90% of Measurements, Not Exceeding	Maximum
(1) Pay quantities, open ground, uniform slopes	1:18,000	1:6,000	1:3,600	1:1,800
(2) Pay quantities, open ground, irregular slopes	1:15,000	1:5,000	1:3,000	1:1,500
(3) Preliminary quantities, open ground, gentle slopes	1:12,000	1:4,000	1:2,400	1:1,200
(4) Preliminary quantities, interfering ground cover, rolling to rugged slopes	1:9,000	1:3,000	1:1,800	1:900

Resource: Photogrammetric Reference Guide Outline published by the American Society of Photogrammetry, dated 1968.

X. SPECIFICATIONS FOR CONVENTIONAL CONTROL

A. HORIZONTAL

- Traverses shall begin and close on existing NGS control or new GPS control stations.

- Coordinates are to be Illinois State Plane and referenced to the NAD83 (North American Datum of 1983), adjustment of 1997.

- All traverses shall be closed traverses with the exception of single “hang-out” points.

- All traverse angles shall be measured eight times using a one-second instrument. If any angle differs from the mean angle by more than five seconds, it shall be rejected.

- Distances shall be measured from each end of the traverse line.

- All “hang-out” points shall be located by a set of eight angles, four on each side of the horizontal circle, to provide a closed circle measurement.

- Distances shall be measured twice and read in meters and feet.

- Traverse closures shall meet or exceed 1:20,000

- Traverse stations established by conventional methods shall be marked by iron pins 5/8" x 30" with local ties in the field book.

B. VERTICAL

The North American Vertical Datum of 1988 shall be used for the vertical reference.

Bench marks established shall be to third-order accuracy (0.05 √M).

Bench marks shall be described with a “To Reach” description and local ties.

C. MATERIAL TO BE DELIVERED

All original horizontal and vertical field notes shall be submitted to IDOT, Aerial Surveys Section, upon completion of the project.

Printouts of traverses with the closure information shall be submitted.

All level notes shall be reduced and adjustments made to all control points.

New bench marks shall be marked to accommodate third-order standards: chiseled squares in concrete, railroad spokes in base of power poles, etc.

Illinois Department of Transportation
Bureau of Design & Environment
Aerial Surveys Section

Request for Photogrammetric Mapping

Aerial Surveys Project:: _____ Accounting Code No.: _____

Date of Request: _____ Needed By: _____

Route - Section - County: _____

Map Attached: ☐ Yes ☐ No

Purpose for Mapping: _____

_____

Total Length: _____

Total Mapping Widths: Planimetry: _____ ft. Contours: _____ ft.

Material Required:

Scale

Standard Topographic Map ☐	Scale 1: _____		
Planimetry Only Map ☐	Contour Interval: _____		
Orthophoto Map ☐			
Plan Profile Sheets	☐ Yes	☐ No	1: _____
ROW Sheets	☐ Yes	☐ No	1: _____
Detail Sheets	☐ Yes	☐ No	1: _____
Photo Mylar Positives	☐ Yes	☐ No	1: _____

Survey Party Available: _____

Remarks: _____

_____

_____

Requested By: _____

Figure 4.1

BDE 2292 (Rev. 10/98)

N

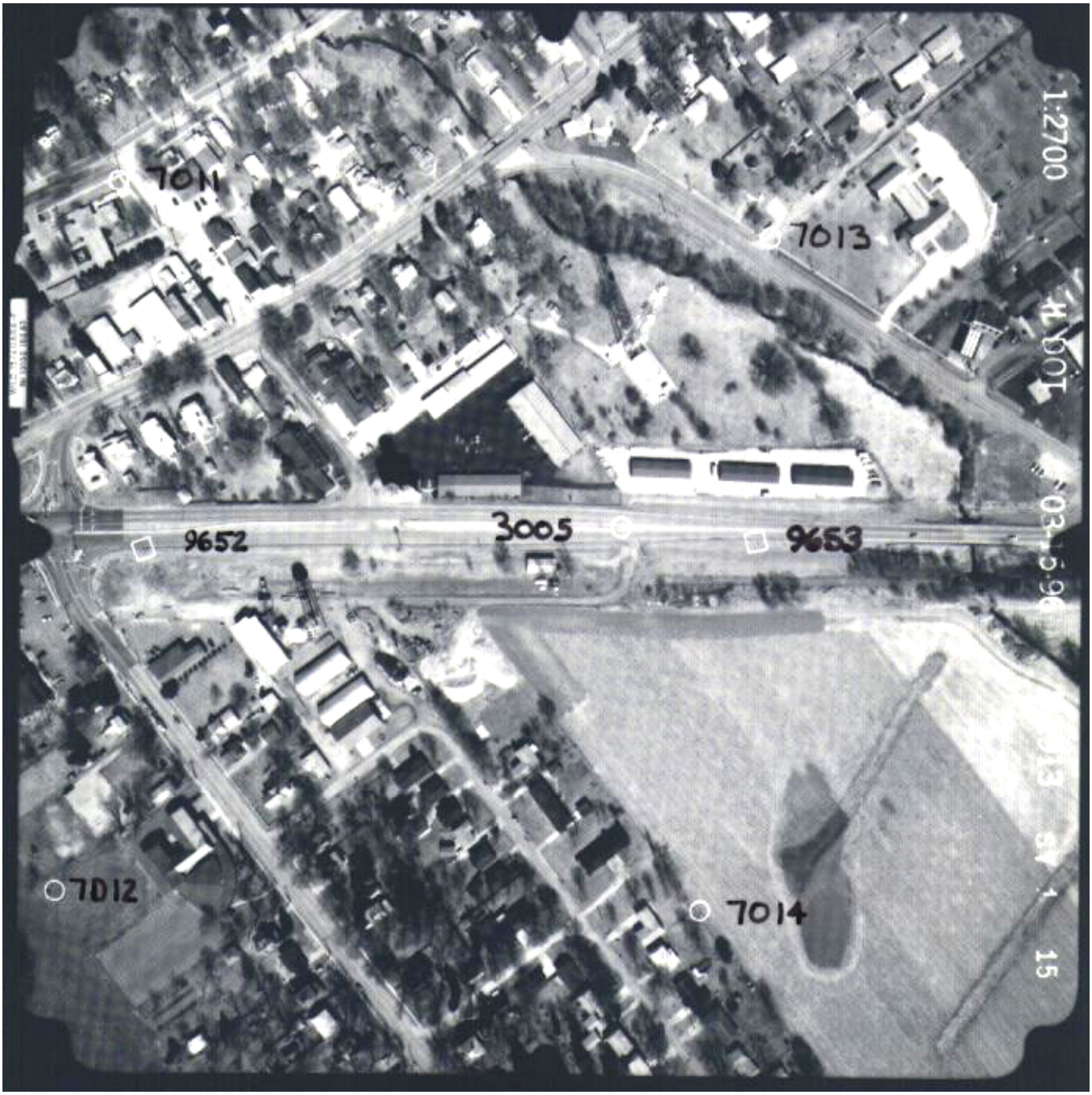

Figure 4.2

N

Figure 4.3

N

Figure 4.4

Backside of photograph D-1834-21 describing a horizontal picture tie (HPT).

Figure 4.4a

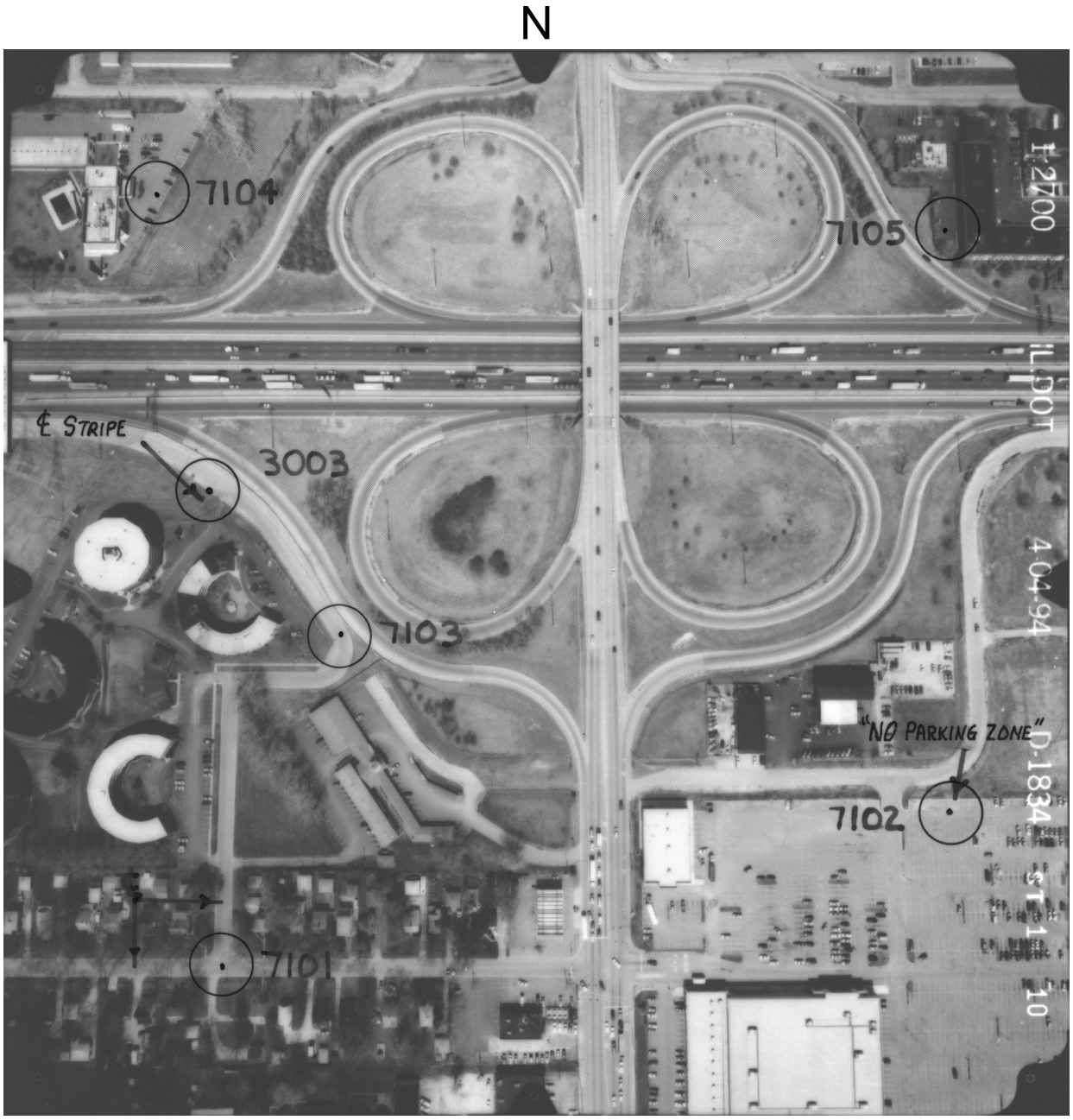
N
7104
7105
7103
7102
7101
3003
℄ STRIPE
"NO PARKING ZONE"
1:2400
ILDOT
4-04-94
D-1834
S11
10

Figure 4.5

Backside of photograph D-1913-10 describing vertical picture ties.

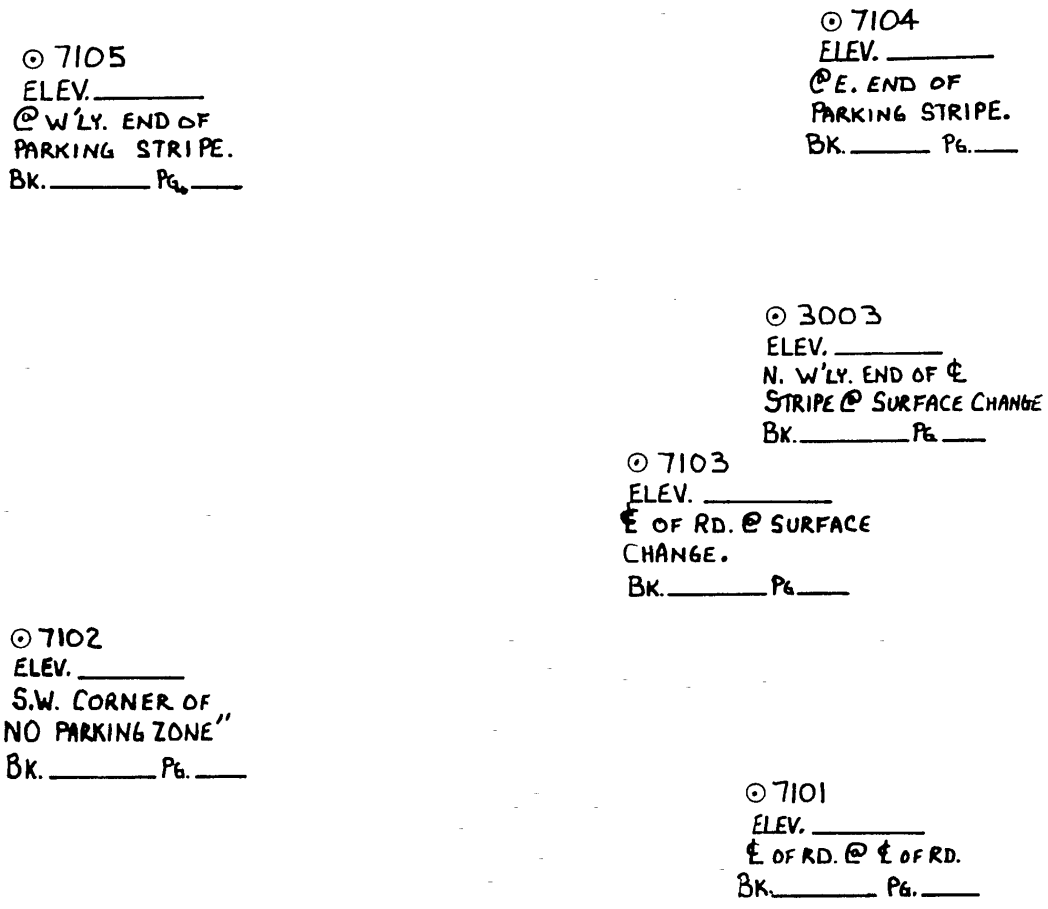

Figure 4.5a